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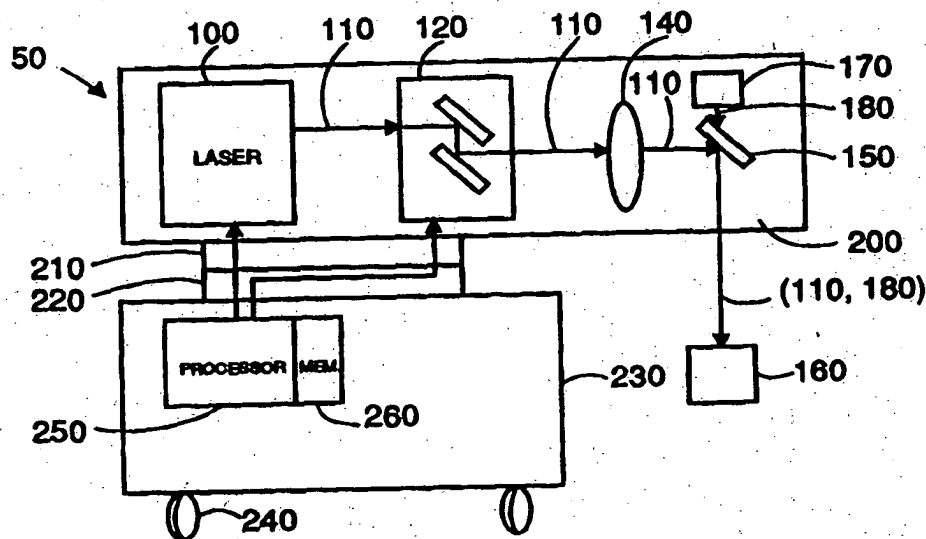
(57) Abstract

Apparatus and method are provided for performing corneal refractive surgery by ablating a portion of a corneal surface of an eye. The apparatus includes a scanner (120) to move a laser beam across a layer to be ablated. A processor (250) determines a first plurality of ablation points substantially within the layer to be ablated. Each of the first plurality of ablation points is defined by a center of the laser beam. The processor (250) determines a second plurality of ablation points to be ablated by the laser beam. Each of the second plurality of ablation points is defined by a center of the laser beam, and each of the second plurality of ablation points is disposed at a location linearly offset from a midpoint between two adjacent ablation points of the first plurality of ablation points in a direction normal to a line defined by the two adjacent ablation points.

MUTUAL INLAID METHOD AND DEVICE FOR SCANNING AN ABLATING LASER BEAM

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an apparatus and method for performing corneal refractive surgery to reshape the corneal surface of the eye and more particularly, to an apparatus and method for scanning a laser beam for smooth corneal reshaping.

Description of Related Art

In order to correct various refractive disorders of the eye, such as myopia, hyperopia, astigmatism, or PTK (phototherapeutic keratectomy), it has been known to use a laser to ablate or remove portions of the cornea to reshape the cornea. Typically, such laser refractive surgery is achieved by ablating a series of successive corneal layers to sculpt, alter, or reshape the cornea.

FIG. 1 is a schematic illustration of a conventional laser scanning method utilized to reshape a cornea. Each corneal layer **10** is ablated by delivering onto the cornea pulsed laser beams at ablation points **12** forming rows **14**. The ablation points **12** are delivered with a step size **S1** maintained between centers of adjacent ones of the laser ablation points **12**. The step size **S1** forms columns **14** of ablation points **12**. There is also a step size **S2** maintained between rows of laser beam ablation points **12**. The step sizes **S1** and **S2** may be equal or one may be greater than the other.

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In ablating successive corneal layers 10, ridges may be formed in the remaining corneal tissue when centers of laser beam ablation points 12 of two or more successive corneal layers 10 repeatedly cause ablation of the same spot on the cornea, or repeatedly miss other spots, or when both of these events occur.

To avoid the formation of ridges in the cornea, the starting point of each row 14 of ablation points 12 is randomized as shown in FIG. 2. This creates non-linear columns 15a of ablation points 12. In addition, the orientation or direction of rows 14 of ablation points 12 is rotated with respect to the previous corneal laser 10 by any arbitrary amount θ, as shown in FIG. 3. By using random starting points for each row 14 of ablation points 12, and by rotating the scanning direction of the rows 14 of ablation points 12 by an arbitrary amount θ, the smoothness of the cornea after layers 10 of corneal tissue are removed is improved. Since the locations of the rows 14 of laser beam ablation points 12 is randomized, the chances of ablation points repeatedly hitting or missing the same relative point on the cornea is reduced somewhat. Nevertheless, there is still a significant possibility for ridges to be formed in the corneal tissue because of the random nature of the locations of the ablation points 12. Thus, there is no guarantee that an ablation point will not hit or miss the same point on subsequent corneal layers 10 when a plurality of corneal layers are ablated.

Accordingly, there is a need to improve the conventional scanning methods to assure smooth ablation of corneal layers and to improve the distribution of the power density of the laser beams across an ablation area.

SUMMARY OF THE INVENTION

It is an object of the invention to fulfill the need referred to above. In accordance with the principles of the present invention, this object is attained by providing an apparatus for performing corneal refractive surgery by
5   ablating a portion of a corneal surface of an eye. The apparatus includes a scanner to move a laser beam across a layer to be ablated. A processor determines a first plurality of ablation points substantially within the layer to be ablated. Each of the first plurality of ablation points is defined by a center of the laser beam. The processor determines a second plurality of ablation
10   points to be ablated by the laser beam. Each of the second plurality of ablation points is defined by a center of the laser beam, and each of the second plurality of ablation points is disposed at a location linearly offset from a midpoint point between two adjacent ablation points of the first plurality of ablation points in a direction normal to a line defined by the two
15   adjacent ablation points.

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

20   FIG. 1 is an enlarged illustration of a conventional scanning method for laser ablation in which laser beam ablation points are distributed evenly in the layer to be ablated;

FIG. 2 is an enlarged illustration of a conventional scanning method for laser ablation in which the starting locations of rows of ablation points

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are selected randomly;

FIG. 3 is an enlarged illustration of a conventional scanning method for laser ablation in which the direction of rows of laser beam ablation points is rotated with respect to a previous ablation layer;

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FIG. 4 is an enlarged illustration of laser beam ablation points determined by a scanning method provided in accordance with the principles of the present invention;

FIG. 5 shows two subsequent ablation layers with the locations of

10   laser beam ablation points determined in accordance with the scanning method of the invention;

FIG. 6 is an enlarged illustration of overlapping laser beam ablation points which result from the scanning method of FIG. 4;

FIG. 7 is schematic illustration of an apparatus for re-profiling a

15   surface of the eye, provided in accordance with the invention; and

FIG. 8 is a flow chart for determining ablation points by the scanning method of the invention.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EXEMPLARY EMBODIMENTS

20   In accordance with a scanning method of the invention, each corneal layer is ablated by delivering rows of pulsed laser beam ablation points onto

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the cornea. As shown in **FIG. 4**, in each row **22** of ablation points **24**, there is step size **S1** between centers of adjacent laser beam ablation points **24**. There is also a step size **S2** between rows **22** of centers of laser beam ablation points **24**. The step sizes **S1** and **S2** can be the equal or unequal.

5   Within the same corneal layer, the starting point of each row **22** is not random as in prior art scanning methods. Instead, the center of each laser beam ablation point **25** on a particular row **22** is disposed linearly offset from a midpoint **27** defined between centers of two adjacent laser beam ablation points **28** and **30** of an adjacent row **32** of laser beam ablation points **24**.

10   The linear offset is normal to a line defining the adjacent row **32**, forming an isosceles triangle between the ablation points **25, 28,** and **30.**

With the scanning method of the invention, for each corneal layer to be ablated, there is no need to rotate the orientation of the rows **22** of laser beam ablation points **24** as in the conventional scanning method shown in

15   **FIG. 3.** Instead, the laser beam ablation points **24** of each layer **10** are evenly distributed in relation to the laser beam ablation points **24** of other ablated corneal layers, such that the center of no two laser beam ablation points **24** will center on an ablation point **24** the same location on the cornea. Even distribution of ablation points in the central area of the cornea is

20   important, since visual acuity is affected greatly at this central area. Ninety degrees rotation of the rows **22** of laser beam ablation points is also permissible.

Not only are the locations of ablation points **24** of adjacent rows **22** not randomized, but neither are the ablation points **24** of one ablated layer

25   with respect to the previous ablated layer. Instead, the ablation points **24** of each ablated layer are evenly distributed in a triangular shape between

adjacent ablation points **24** on each ablated layer, and the ablation points **24** of subsequent ablation layers are determined to provide a smooth ablation avoiding the formation of corneal ridges. For instance, **FIG. 5** shows subsequent ablated layers **A** and **B** having ablation points **40** and **42**, respectively. The ablation points **40**, **42** on each ablated layer **A**, **B**, are located in accordance with the scanning method of the invention.

As seen in (c) of **FIG. 5**, the ablation points **42** of a subsequent ablation layer **B** are centered within the triangle **T** formed by adjacent ones of the ablation points **40** on the previous ablation layer **A**. Similarly, the ablation points on an ablation layer ablated after ablation layer **B** (not shown) are centered within the triangle shapes formed by adjacent ones of the ablation points **42** on ablation layer **B**. Thus, the locations of ablation points on subsequent layers are not randomized with respect to the previous layer, but instead are determined to provide an even distribution of power density not only with respect to each individual ablation layer, but also with respect to subsequent ablation layers. This even distribution of power density prevents the formation of corneal ridges.

Thus, it can seen that the laser beam ablation delivered by the scanning method of the invention results in generally evenly distributed laser beam ablation points. Ideally, no ablation point on any particular layer is co-located with an ablation point on an adjacent ablation layer.

FIG. 6 is an enlarged view of the overlap of ablation by a laser beam centered at adjacent ablation points delivered by the scanning method of the invention. The power density of overlapping laser beam ablation points is distributed more evenly than that of conventional scanning methods. Thus, the power of each of the three laser beams **34**, **36** and **38** of **FIG. 6**

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supplement each other at perimeter areas **37** such that the ablation is more evenly distributed across the ablation area.

In another embodiment of the scanning method of the invention, the distribution of laser beam ablation points of each ablation layer is arranged depending on the total number of ablation layers, in order to evenly distribute the ablation points. In this way, the center point of no two ablation points on any ablation layer are co-located.

Referring to FIG. 7, a refractive laser system **50** provided in accordance with the present invention is shown which is capable of performing the scan and ablation defined above. The refractive laser system **50** comprises a laser **100** having UV (preferably 193-220 nm) or IR (0.7-3.2 μm) wavelength to generate a beam **110**. A scanning device **120** capable of controllably changing the incident angle of the laser beam **110** passes the angled beam **110** to the focusing optics **140**, onto a reflecting mirror **150** which adjusts an impinging angle of the laser beam **110** onto the target area **160**. The laser beam **110** preferably has an energy level less than 10 mJ/pulse. The target **160** is the cornea of an eye.

An aiming system **170** has a visible wavelength light beam **180** (preferably from a laser diode or He-Ne laser) adjusted to be co-linear with the ablation laser beam **110** to aid adjustment of the normal incident angle. The basic laser head **200** is steered by a motorized stage for X and Y horizontal directions **210**, and a motorized stage for the vertical (height) direction **220**, which assures the focusing beam spot size and concentration of the beam onto the cornea. Of course, the laser head **200** may be of the stationary kind when the patient is disposed on a movable bed or chair. The refractive laser system **50** has a control panel **230** including a processor

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250 for controlling the laser **100**, for controlling scanning device **120**, for controlling the angle of the beam **110**, and for controlling all other aspects of the refractive laser system **50**. Wheels **240** are provided to make the refractive laser system **50** portable.

5   The basic laser head **200** and control panel **230** are of the type disclosed in U.S. Patent No. 5,520,679, the content of which is hereby incorporated by reference into the present specification. However, in accordance with the invention, the processor **250** in the form of a microprocessor, digital signal processor, or microcontroller, includes in

10   program memory **260** the procedures necessary to control the scanning device **120** to ensure that each laser beam ablation point **25** on a particular row **22** of laser beam ablation points **24** is disposed linearly offset from a midpoint **27** defined between two adjacent laser beam ablation points **28**, **30** of an adjacent row **32** of laser beam ablation points **24** (**FIG. 4**), thereby

15   defining the scanning technique of the invention. In particular, with reference to **FIG. 8**, the processor **250** controls the scanning device **120** by initially locating a first ablation point on a first row of ablation points at step **300**. Next, at step **310**, a second ablation point is located on the first row by stepping a distance **S1** in the x and/or y-directions. The remaining ablation

20   points on the first row are completed as indicated at step **315**. At step **320**, a midpoint **M** between the first and second ablation points of the first row is determined. Thereafter, in step **330**, a second row of ablation points is located by stepping normal to the first row a distance **S2**. With the second row located, ablation points on the second row are located at points linearly

25   offset from the midpoints of ablation points on an adjacent row, as indicated in step **340**. Thereafter, the remaining ablation points on the second row are completed, as indicated in step **350**, as are the ablation points for all

remaining rows as indicated in step **360**.

Subsequent ablation layers' ablation points are determined with respect to previous layers' ablation points in step **370**, and all remaining ablation layers are completed in accordance with the disclosed scanning method, as indicated in step **380**.

It can be appreciated by employing the apparatus of the invention having the inventive scanning technique, a laser beam ablation point of one ablated layer can be controlled to not occur at the same location as a laser beam ablation point of any other ablated layer. Thus, the resulting ablated area is smoother than conventional ablated areas, and the power density of the laser beams is distributed more evenly than that of conventional techniques.

It has thus been seen that the objects of this invention have been fully and effectively accomplished. It will be realized, however, that the foregoing preferred embodiments have been shown and described for the purposes of illustrating the structural and functional principles of the present invention, as well as illustrating the methods of employing the preferred embodiments and are subject to change without departing from such principles. Therefore, this invention includes all modifications encompassed within the spirit of the following claims.

What is claimed is:

1. A method of locating a starting point for a row of equally spaced ablation points, said method comprising:

selecting a first starting point for a first row of ablation points;

causing ablation at each of said first row of ablation points;

selecting a second starting point for a second row of ablation points, said second starting point being linearly offset from a point between two adjacent ones of said first row of ablation points in a direction normal to a line defined by said two adjacent ones of said first row of ablation points; and

causing ablation at each of said second row of ablation points.

2. The method according to claim 1, wherein said point is a midpoint between said two adjacent ones of said first row of ablation points. –

3. The method according to claim 1, further comprising:

defining an ablation area.

4. Apparatus to locate starting coordinates of a row of equally spaced ablation points comprising:

memory to store coordinates of a first row of ablation points;

a module to determine a closest point on a second row of ablation points to a midpoint between coordinates of two of said first row of ablation points based on an estimated starting coordinate of a second row of ablation points; and

establishing said closest point as a final starting coordinate for said second row of ablation points.

5. Apparatus according to claim 4, wherein:

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said first row of ablation points are equally spaced.

6. Apparatus according to claim 4, further comprising:

a module to ensure that all subsequent ablation layers are prevented from centering an ablation beam at any coordinate corresponding to any ablation point in said first or second rows.

7. A method of ablating a surface area, comprising:

defining an ablation layer area;

centering a laser beam at each of a first plurality of ablation points along a first row substantially within said ablation layer area;

causing said laser beam to ablate said surface area corresponding to each of said first plurality of ablation points;

centering said laser beam at a second plurality of ablation points along a second row substantially within said ablation layer area, each of said second plurality of ablation points of said second row being disposed at a location linearly offset from a point defined between two adjacent ablation points of said first plurality of ablation points in a direction normal to a line defined by said two adjacent ablation points, and

causing said laser beam to ablate said surface area corresponding to each of said second plurality of ablation points.

8. The method of ablating according to claim 7, wherein:

said point is a midpoint between said two adjacent ablation points of said first plurality of ablation points.

9. The method of ablating according to claim 7, wherein:

said ablation layer area is an area of corneal tissue.

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10. Apparatus for scanning an ablating laser beam across an ablation layer of a surface, comprising:

a scanner to move said ablating laser beam with respect to said surface;

a processor to determine a first plurality of ablation points substantially within said ablation layer, each of said first plurality of ablation points being defined by a center of said laser beam; and

a module to determine a second plurality of ablation points to be ablated by said laser beam, each of said second plurality of ablation points being defined by a center of said laser beam, and each of said second plurality of ablation points being disposed at a location linearly offset from a point defined between two adjacent ablation points of said first plurality of ablation points in a direction normal to a line defined by said two adjacent ablation points.

11. The apparatus for scanning said ablating laser beam according to claim 10, wherein:

said point is a midpoint between said two adjacent ablation points of said first plurality of ablation points.

12. The apparatus for scanning said ablating laser beam according to claim 10, wherein:

said ablation layer is a layer of corneal tissue.

13. Apparatus for performing corneal refractive surgery by ablating a portion of a corneal surface of an eye, said apparatus comprising:

a pulsed laser to produce a pulsed output beam;

a scanner to scan said pulsed output beam across said corneal surface of said eye; and

a processor operatively associated with said scanner to deliver said pulsed output beam to said portion of said corneal surface of said eye to define first and second rows of laser beam ablation points, each of said second row of laser beam ablation points being disposed at a location linearly offset, in a direction normal to said first row of laser ablation points, from a midpoint between two closest adjacent ones of said first row of laser beam ablation points.

14. The apparatus according to claim 13, wherein:

said pulsed laser is a UV pulsed laser having an energy level less than 10 mJ/pulse.

15. The apparatus according to claim 13, wherein:

said pulsed laser has an output wavelength between 193 and 220 nanometers.

16. Apparatus to locate a starting point for a row of equally spaced ablation points, said apparatus comprising:

selecting means for selecting a first starting point for a first row of ablation points, and a second starting point for a second row of ablation points, said second starting point being linearly offset from a point between two adjacent ones of said first row of ablation points in a direction normal to a line defined by said two adjacent ones of said first row of ablation points; and

ablation means for causing ablation at each of said first row of ablation points and at each of said second row of ablation points.

17. Apparatus according to claim 16, wherein said point is a midpoint between said two adjacent ones of said first row of ablation points.

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18. Apparatus to locate starting coordinates of a row of equally spaced ablation points comprising:

storing means for storing coordinates of a first row of ablation points;

determining means for determining a closest point on a second row of ablation points to a midpoint between coordinates of two of said first row of ablation points based on an estimated starting coordinate of a second row of ablation points; and

establishing means for establishing said closest point as a final starting coordinate for said second row of ablation points.

19. Apparatus according to claim 18, wherein:
said first row of ablation points are equally spaced.

20. Apparatus according to claim 18, further comprising:
means for ensuring that all subsequent ablation layers are prevented from centering an ablation beam at any coordinate corresponding to any ablation point in said first or second rows.

AMENDED CLAIMS

[received by the International Bureau on 31 March 1999 (31.03.99);
original claims 1-20 replaced by new claims 1-28 (8 pages)]

1. A method of locating a starting point for a row of equally spaced ablation points, comprising:

selecting a first starting point for a first row of ablation points;

selecting a second starting point for a second row of ablation points, said second starting point being linearly offset from a point between two adjacent ones of said first row of ablation points in a direction normal to a line defined by said two adjacent ones of said first row of ablation points; and

scanning a laser beam to cause a center of said laser beam to be incident on, and to ablate, each ablation point of said first and second row of ablation points.

2. The method according to claim 1, wherein said point is a midpoint between said two adjacent ones of said first row of ablation points.

3. The method according to claim 1, further comprising:

defining an ablation area.

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4. An apparatus to locate starting coordinates of a row of equally spaced ablation points on a surface to be ablated by a laser beam scanned across said surface, comprising:

memory to store coordinates of a plurality of ablation points including a first row of ablation points;

a module to determine a closest point on a second row of ablation points to a midpoint between coordinates of two of said first row of ablation points based on an estimated starting coordinate of a second row of ablation points, and establishing said closest point as a final starting coordinate for said second row of ablation points; and

a scanning device to receive said final starting coordinate from said module to cause said laser beam to be incident on a location on said surface corresponding to said final starting coordinate.

5. The apparatus according to claim 4, wherein:
said first row of ablation points are equally spaced.

6. The apparatus according to claim 4, further comprising:
a module to ensure that said laser beam is prevented from being centered on any coordinate corresponding to any ablation point in at least one of said first and second rows in subsequent ablation layers.

AMENDED SHEET (ARTICLE 19)

7. A method of ablating a surface area, comprising:

defining an ablation layer area;

scanning a laser beam across said surface to center said laser beam at each of a first plurality of ablation points along a first row substantially within said ablation layer area;

causing said laser beam to ablate said surface area corresponding to each of said first plurality of ablation points;

scanning said laser beam across said surface to center said laser beam at a second plurality of ablation points along a second row substantially within said ablation layer area, each of said second plurality of ablation points of said second row being disposed at a location linearly offset from a point defined between two adjacent ablation points of said first plurality of ablation points in a direction normal to a line defined by said two adjacent ablation points, and

causing said laser beam to ablate said surface area corresponding to each of said second plurality of ablation points.

8. The method of ablating according to claim 7, wherein:

said point is a midpoint between said two adjacent ablation points of said first plurality of ablation points.

9. The method of ablating according to claim 7, wherein:

said ablation layer area is an area of corneal tissue.

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10. An apparatus for scanning an ablating laser beam across an ablation layer of a surface, comprising:

a processor to determine a first plurality of ablation points substantially within said ablation layer, each of said first plurality of ablation points being defined by a center of said laser beam;

a module to determine a second plurality of ablation points to be ablated by said laser beam, each of said second plurality of ablation points being defined by a center of said laser beam, and each of said second plurality of ablation points being disposed at a location linearly offset from a point defined between two adjacent ablation points of said first plurality of ablation points in a direction normal to a line defined by said two adjacent ablation points; and

a scanning device to scan said ablating laser beam across said ablation layer to center said ablating laser beam at locations on said surface corresponding to said first and said second plurality of ablation points.

11. The apparatus for scanning said ablating laser beam according to claim 10, wherein:

said point is a midpoint between said two adjacent ablation points of said first plurality of ablation points.

12. The apparatus for scanning said ablating laser beam according to claim 10, wherein:

said ablation layer is a layer of corneal tissue.

AMENDED SHEET (ARTICLE 19)

13. An apparatus for performing corneal refractive surgery by ablating a portion of a corneal surface of an eye, said apparatus comprising:

a pulsed laser to produce a pulsed output beam;

a scanner to scan said pulsed output beam across said corneal surface of said eye; and

a processor operatively associated with said scanner to deliver said pulsed output beam to said portion of said corneal surface of said eye to define first and second rows of laser beam ablation points, each of said second row of laser beam ablation points being disposed at a location linearly offset, in a direction normal to said first row of laser ablation points, from a midpoint between two closest adjacent ones of said first row of laser beam ablation points.

14. The apparatus according to claim 13, wherein:

said pulsed laser is a UV pulsed laser having an energy level less than 10 mJ/pulse.

15. The apparatus according to claim 13, wherein:

said pulsed laser has an output wavelength between 193 and 220 nanometers.

16. An apparatus to locate a starting point for a row of equally spaced ablation points, said apparatus comprising:

selecting means for selecting a first starting point for a first row of ablation points, and a second starting point for a second row of ablation points, said second starting point being linearly offset from a point between two adjacent ones of said first row of ablation points in a direction normal to a line defined by said two adjacent ones of said first row of ablation points; and

scanning means for scanning a laser beam to cause said laser beam to center at, and thereby causing ablation of, each of said first row of ablation points and at each of said second row of ablation points.

17. The apparatus according to claim 16, wherein said point is a midpoint between said two adjacent ones of said first row of ablation points.

18. An apparatus to locate starting coordinates of a row of equally spaced ablation points on a surface, comprising:

storing means for storing coordinates of a plurality of ablation points including a first row of ablation points;

determining means for determining a closest point on a second row of ablation points to a midpoint between coordinates of two of said first row of ablation points based on an estimated starting coordinate of a second row of ablation points;

establishing means for establishing said closest point as a final starting coordinate for said second row of ablation points; and

scanning means for scanning a laser beam across said surface to cause said laser beam to be centered at a location on said surface corresponding to said final starting coordinate.

AMENDED SHEET (ARTICLE 19)

19. The apparatus according to claim 18, wherein:

said first row of ablation points are equally spaced.

20. The apparatus according to claim 18, further comprising:

means for ensuring that said laser beam is prevented from being centered on any coordinate corresponding to any ablation point in at least one of said first and second rows in subsequent ablation layers.

21. The method of locating said starting point according to claim 1, wherein said step of scanning comprises:

moving at least one scanning mirror of a scanning device to cause said center of said laser beam to be incident on each ablation point of said first or said second row of ablation points.

22. The apparatus to locate starting coordinates in accordance with claim 4, wherein said scanning device comprises:

at least one scanning mirror for directing said laser beam.

23. The apparatus according to claim 4, further comprising:

a module to ensure that any coordinate already stored in said memory are precluded in subsequent ablation layers.

24. The method of ablating a surface area according to claim 7, wherein each of said steps of scanning comprises:

moving at least one scanning mirror of a scanning device to cause said laser beam to center at each ablation point of at least one of said first and said second plurality of ablation points.

25. The apparatus for scanning an ablating laser beam in accordance with claim 10, wherein said scanning device comprises:

at least one scanning mirror for directing said ablating laser beam.

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26. The apparatus for performing corneal refractive surgery in accordance with claim 13, wherein said scanner comprises:

at least one scanning mirror to direct said pulsed output beam.

27. The apparatus to locate a starting point in accordance with claim 16, wherein said scanning means comprises:

at least one scanning mirror to direct said laser beam.

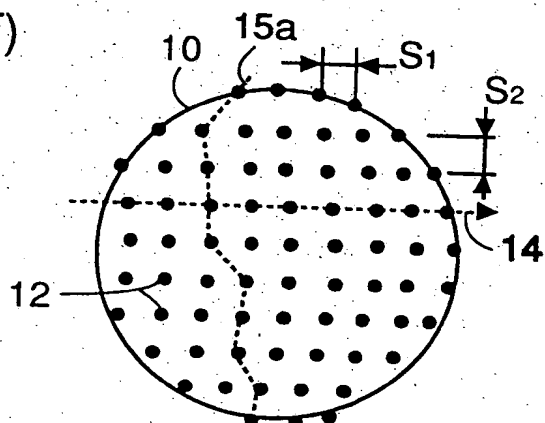28. Apparatus according to claim 18, wherein said scanning means comprises:

at least one scanning mirror to direct said laser beam.

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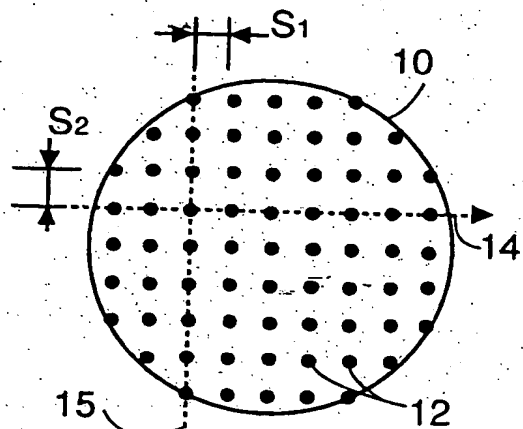
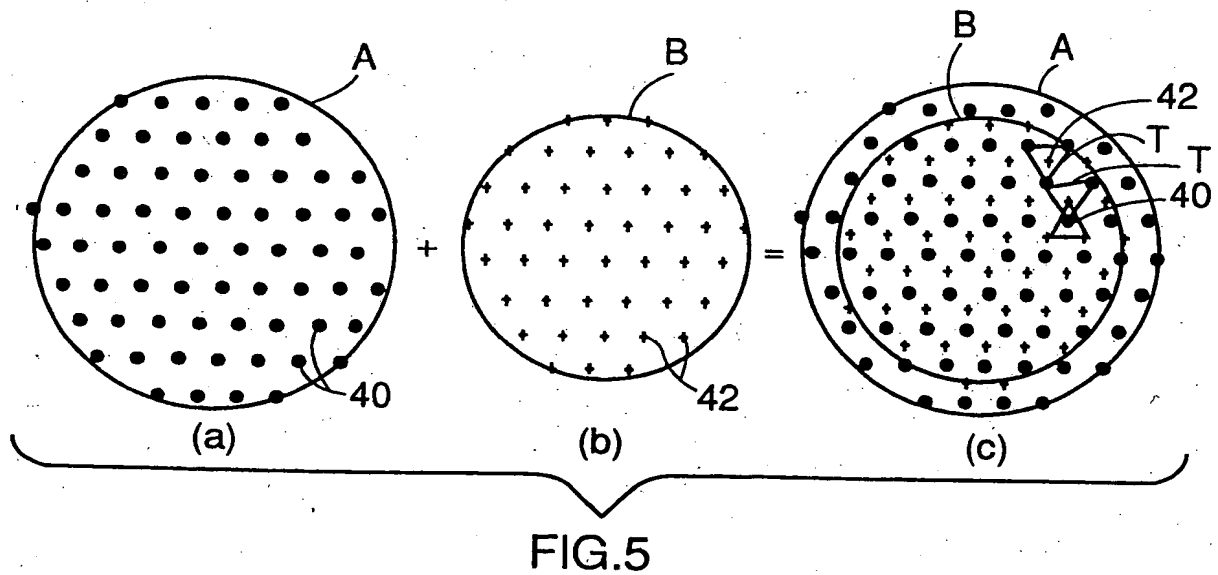FIG. 1 (PRIOR ART)

FIG. 2 (PRIOR ART)

FIG. 3 (PRIOR ART)

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FIG. 4

FIG. 6

FIG.5
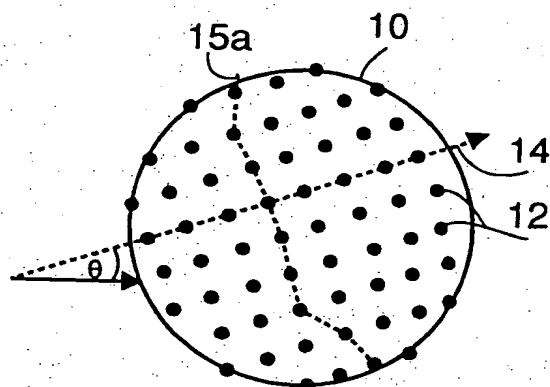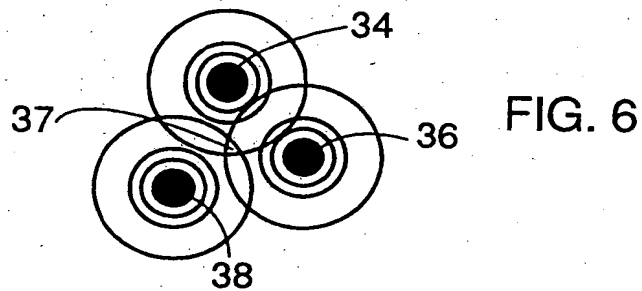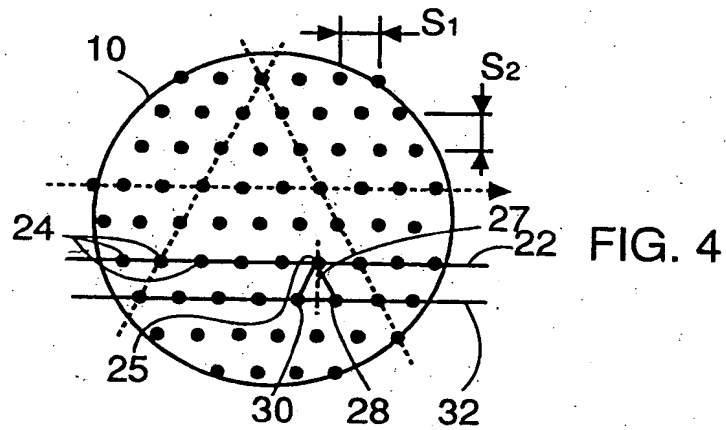
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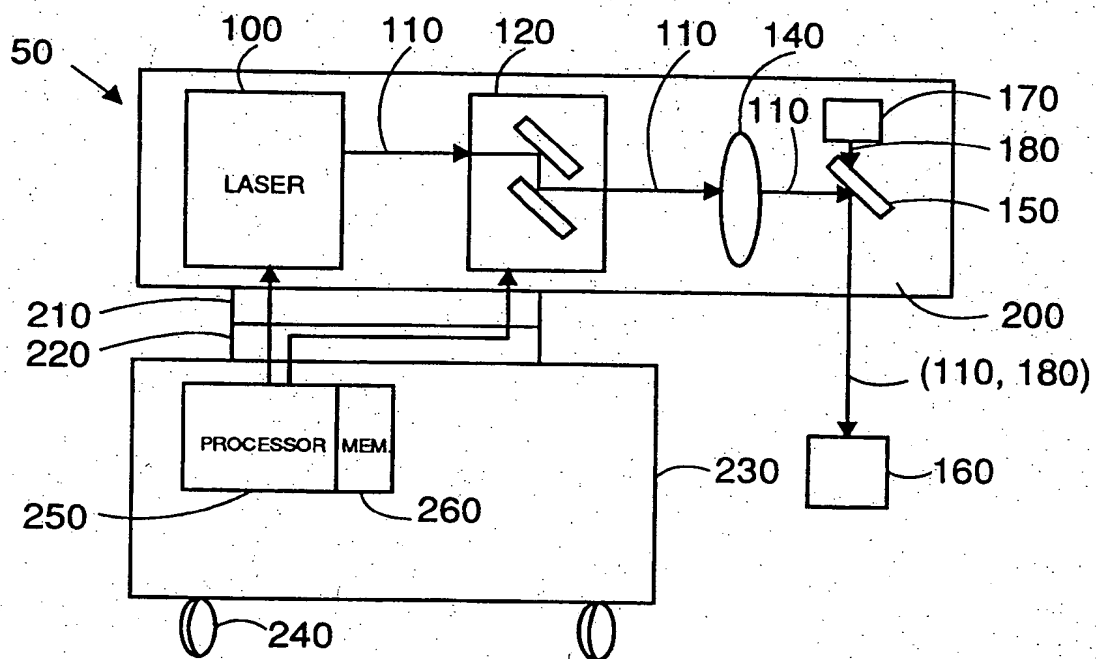
FIG. 7

FIG. 8

INTERNATIONAL SEARCH REPORT

A.   CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61N 5/02.

US CL   :606/10

According to International Patent Classification (IPC) or to both national classification and IPC

B.   FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 606/3-6, 9-18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,653,495 A (NANAUMI) 31 March 1987, entire document.	1-20
Y	WO 87/06478 A (BUYS et al.) 04 November 1987, entire document.	1-20

☐   Further documents are listed in the continuation of Box C.   ☐   See patent family annex.

*	Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	
"B"	earlier document published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	
"P"	document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 FEBRUARY 1999	**1 2 MAR 1999**
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized Officer DAVID M. SHAY Telephone No. (703) 308-2215

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